Primordial Black Holes and r-Process Nucleosynthesis

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WIN-2017 @ UC-Irvine

(6.20.2017)

Based on: George Fuller, Alex Kusenko, VT [arXiv:1704.01129] *(accepted to PRL)*

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- PBH appear in many BSM scenarios and strictly, don't require non-SM physics

  → **plausible that regardless of DM origin, some in PBH !**

Motivation: PBH formation

- PBH formation: density contrast $\frac{\delta\rho}{\rho} \sim \mathcal{O}(1)$ within horizon → collapse to BH

  ... *improbable without new physics*

see reviews
[Carr,Kuhnel,Sandstad,17; Khlopov,10]

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- Thus, PBHs can span vast mass range (with mass spectrum):

General Setup

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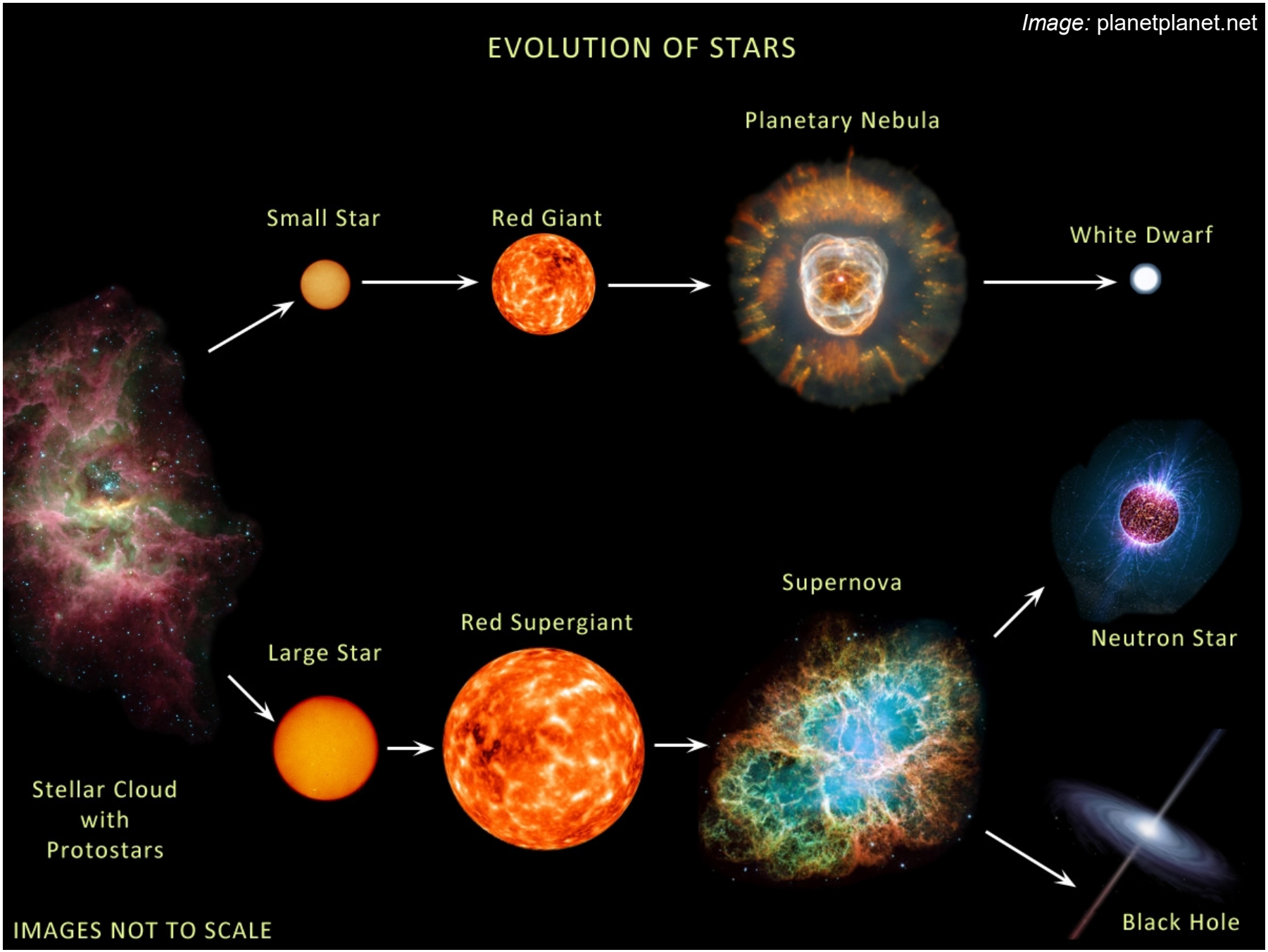
→ **what are the astrophysical consequences?**

Neutron Star Formation



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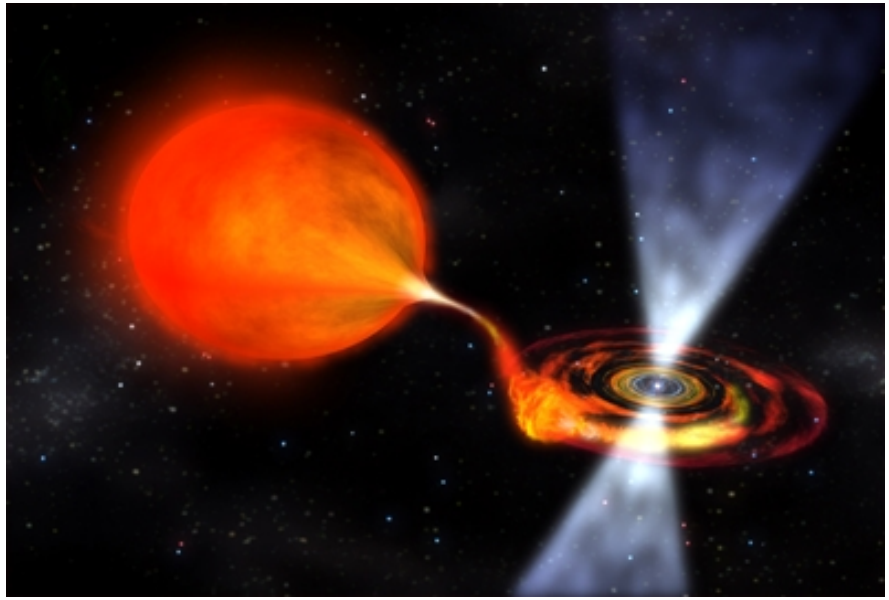
  → binary pulsar accretes matter from companion, spun-up and "recycled" → MSP

Image: NASA/Dana Berry



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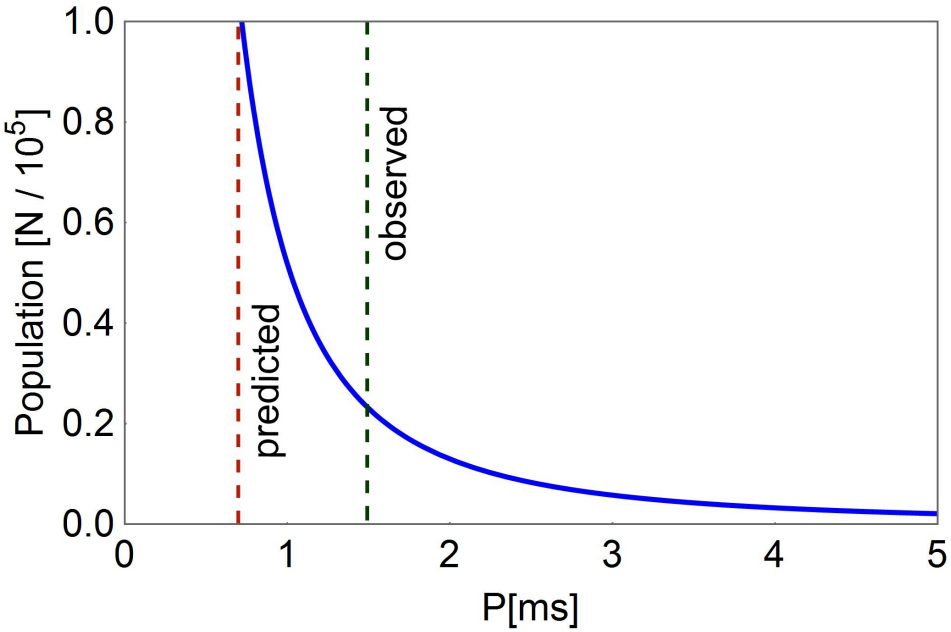
- Population vs. rotation period: [Cordes,Chernoff,97; Lorimer,13]



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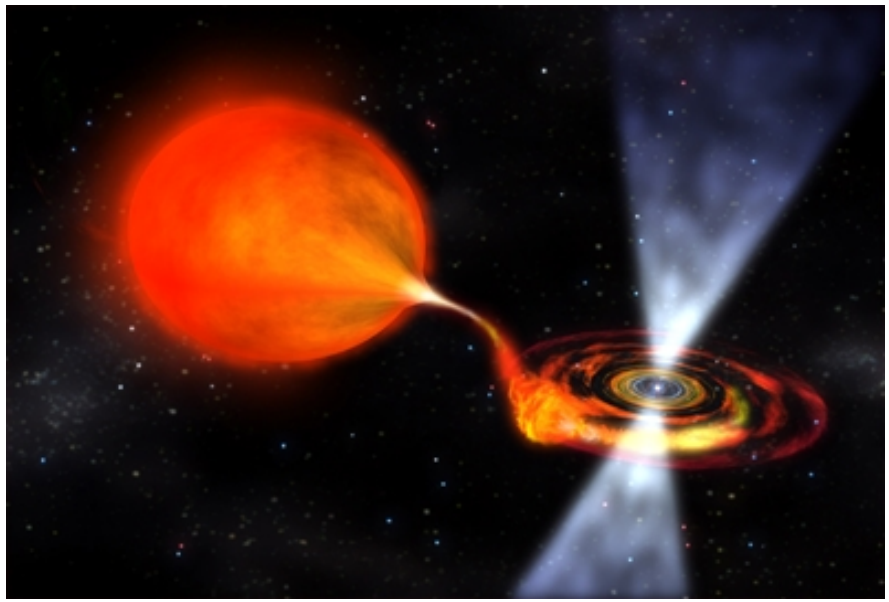

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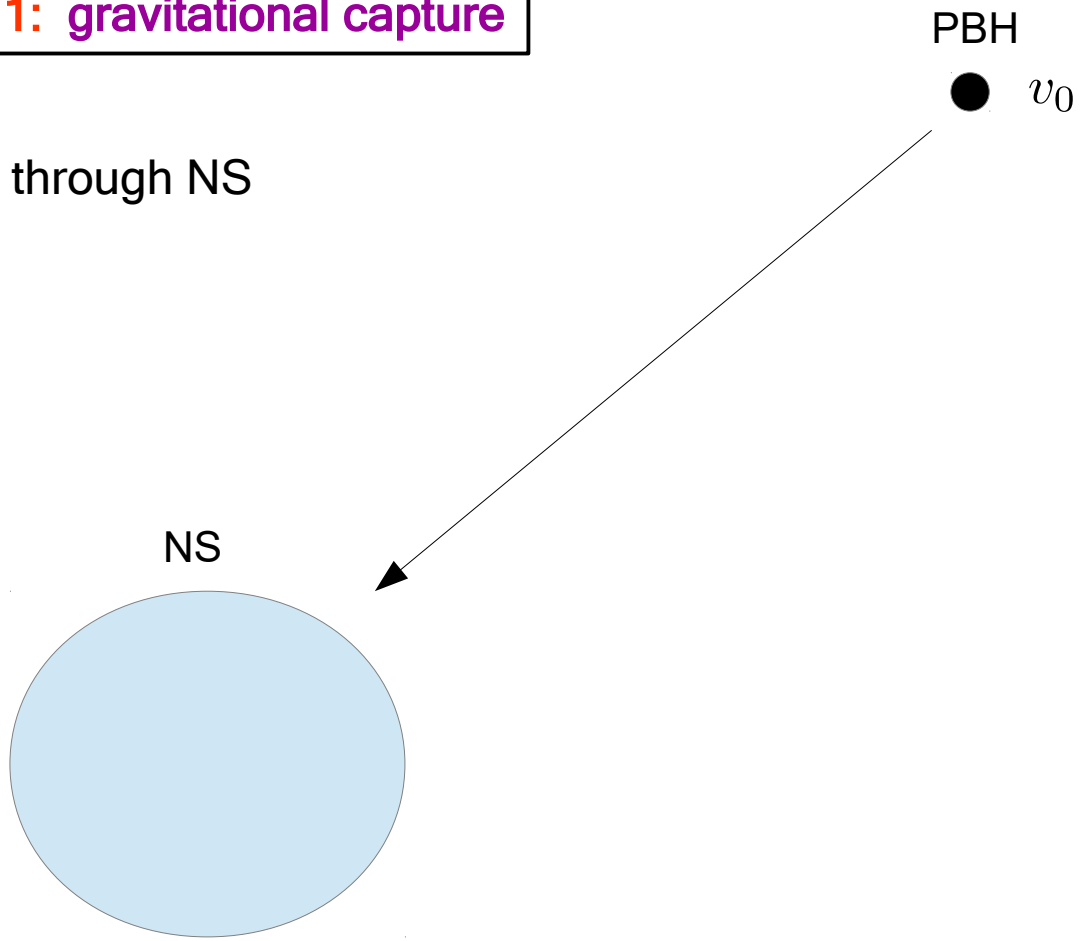

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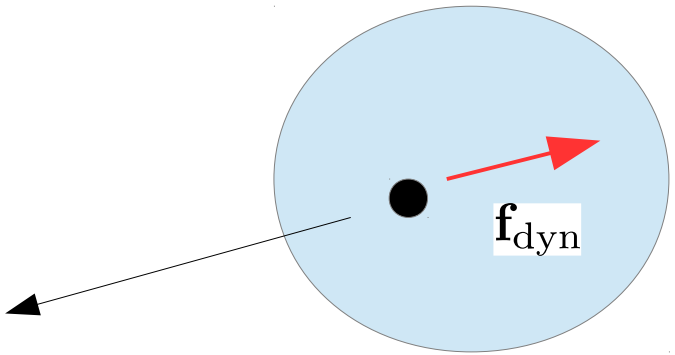

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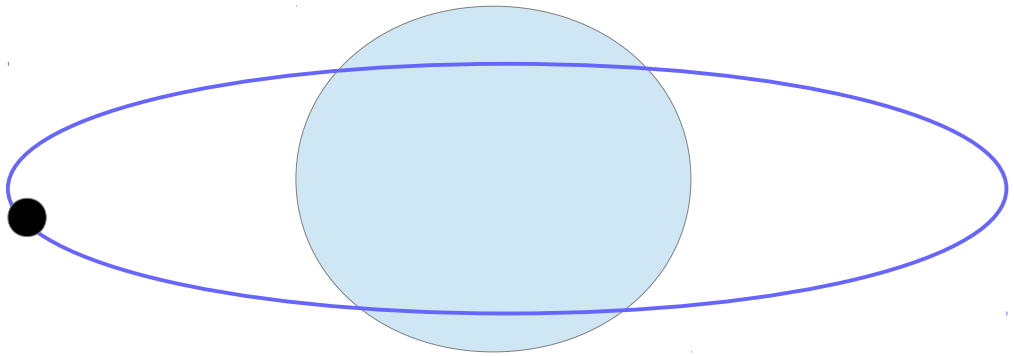

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capture rate: $$F = \left(\frac{\Omega_{\rm PBH}}{\Omega_{\rm DM}}\right) F_0[m_{\rm PBH}, \rho_{\rm DM}, \overline{v}, R_{\rm NS}, R_s]$$

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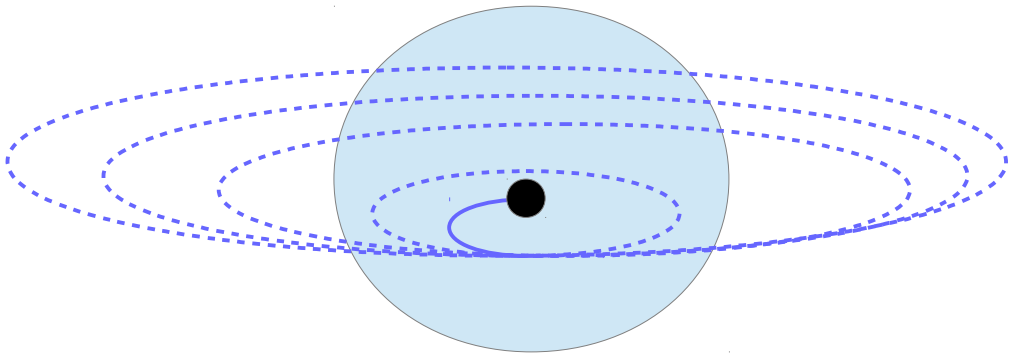
Stage 2: PBH in NS

→ captured PBH continues passing through NS, until it settles inside

settle time: $$t_{\rm set} \simeq 4.1 \times 10^4 \left(\frac{m_{\rm PBH}}{10^{22}{\rm g}}\right)^{-3/2} {\rm yr}$$



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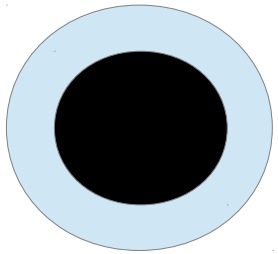
Stage 3: BH grows inside

→ PBH inside NS grows via Bondi spherical accretion, consuming the host star

consume time: $$t_{\rm con} \simeq 10^{-2} \left(\frac{10^{22} {\rm g}}{m_{\rm PBH}} \right) {\rm yr}$$



Pulsar Lifetime

- Pulsar lifetime: $\langle t_{\rm NS} \rangle = 1/F + t_{\rm set} + t_{\rm con}$

- Find $O(1-10)\%$ of NS consumed in Galactic time

  → consistent with observed missing pulsars [Dexter,O'Leary,14]

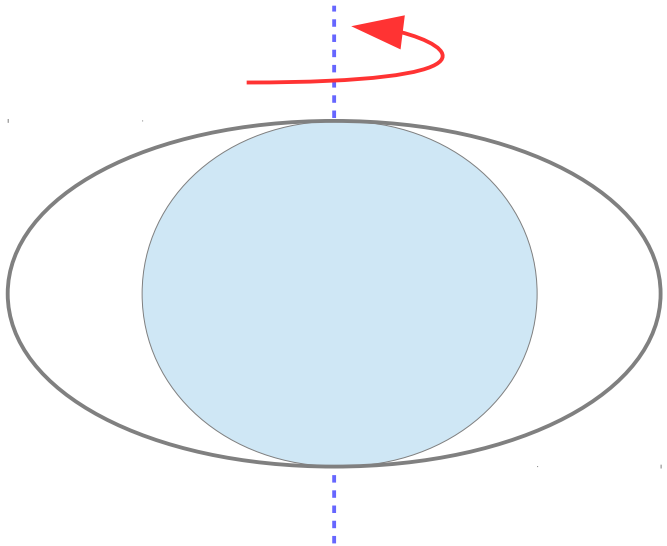
Bonus: consistent with recently discovered young GC magnetar [Mori+,13; Kennea+,13]

→ shows unusual activity … a hint of BH consumption ??

Growing BH in NS: angular momentum transfer

- MSP spinning near mass shedding limit → elongated spheroid (Roche lobe model)

[Shapiro,Teukolsky,83]



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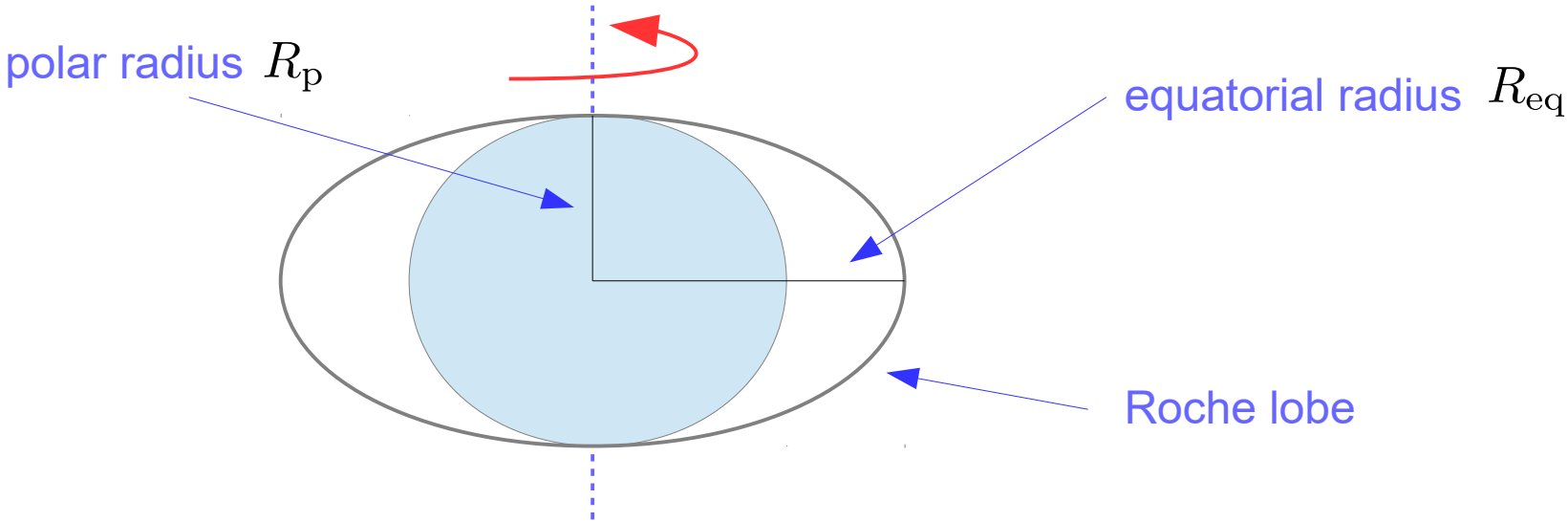

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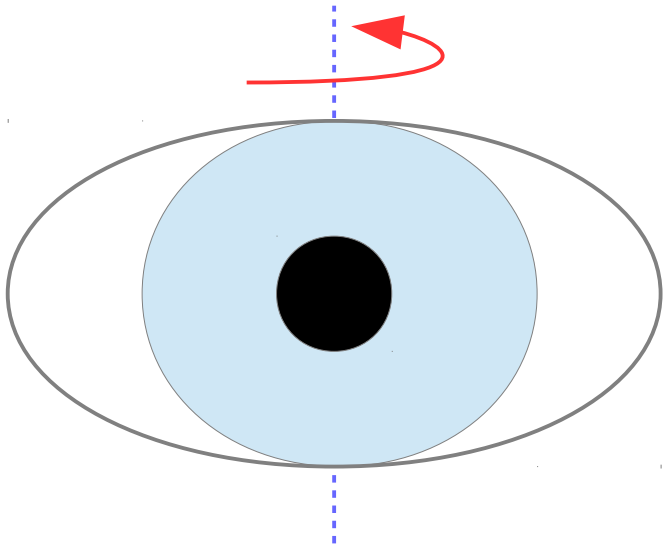

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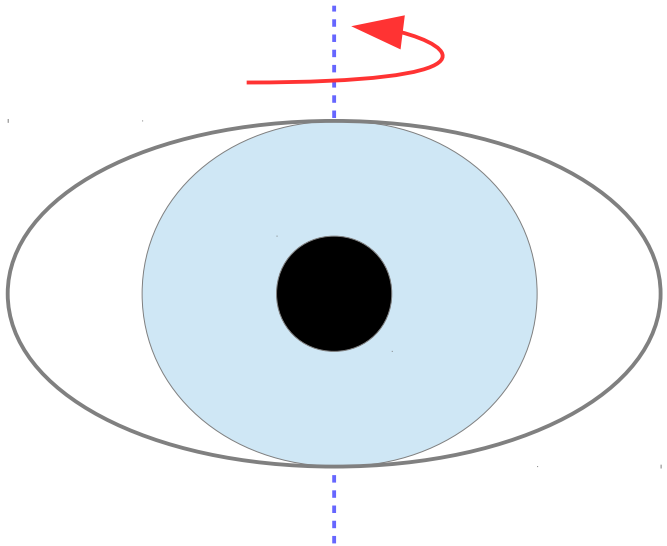

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* Differential rotation can occur → calculated that viscosity and magnetic stresses eliminate

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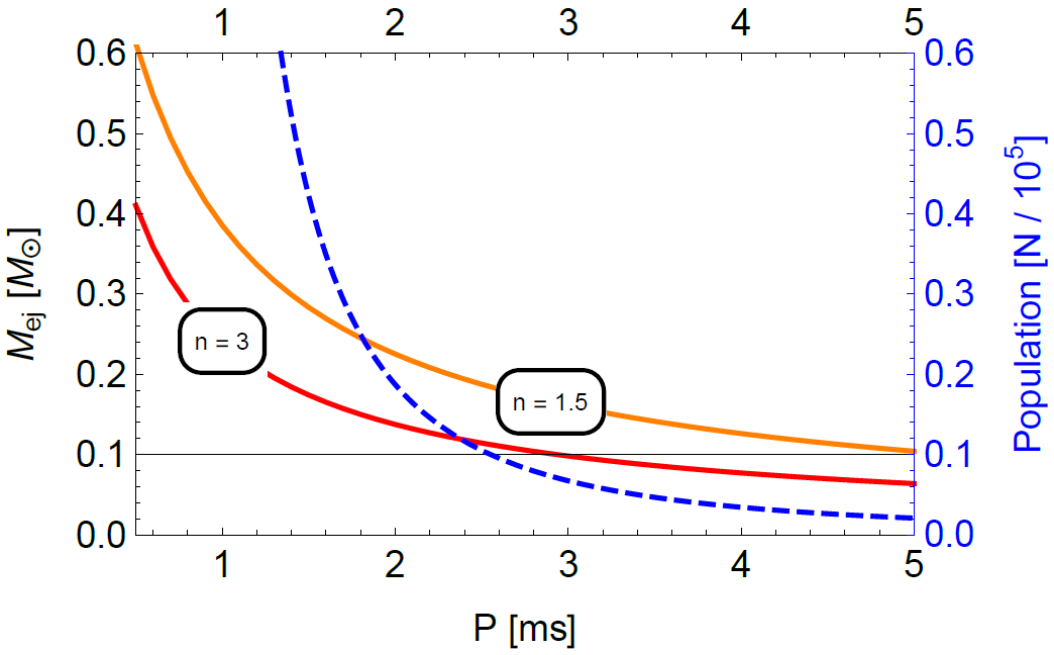

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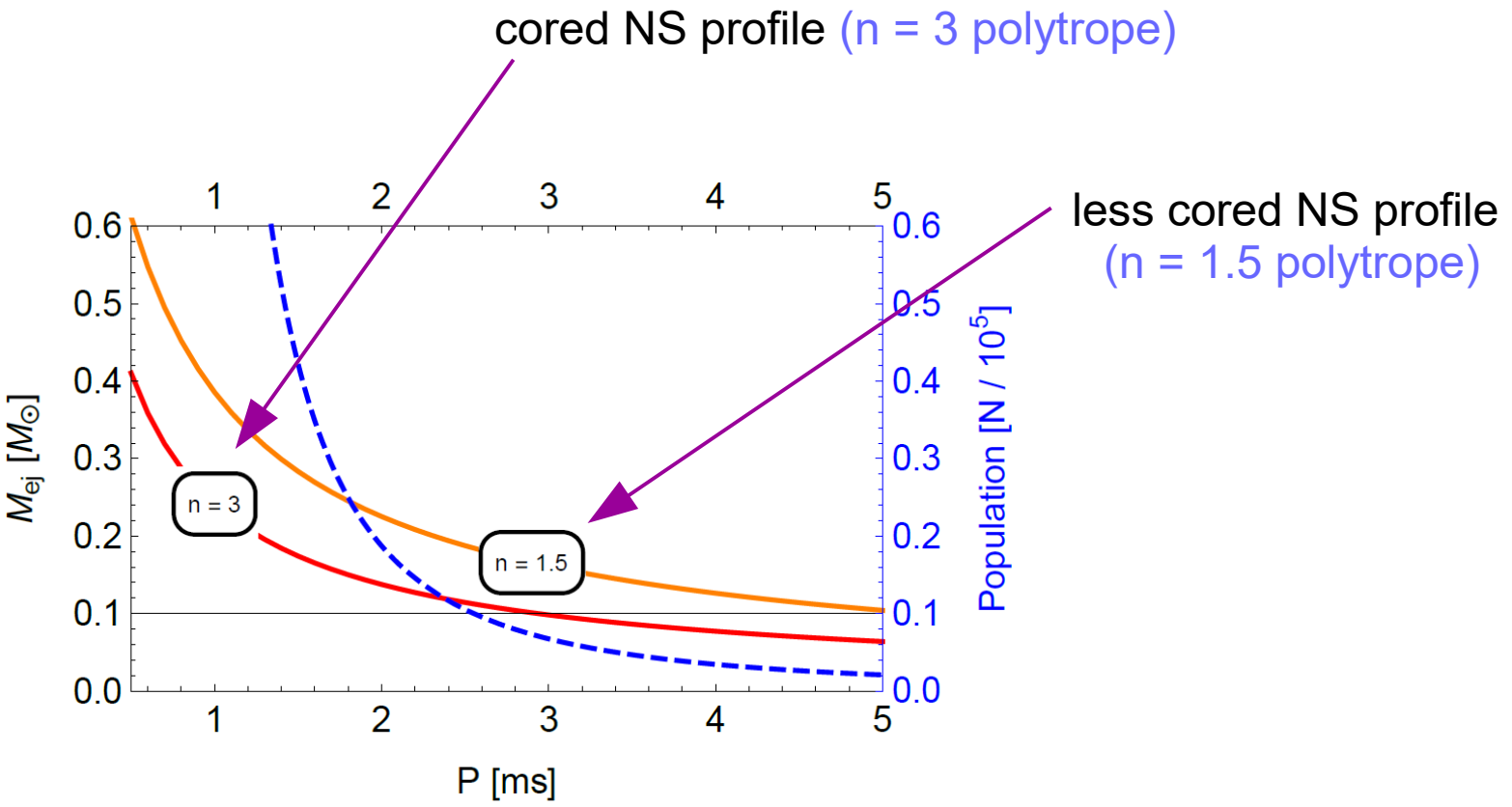

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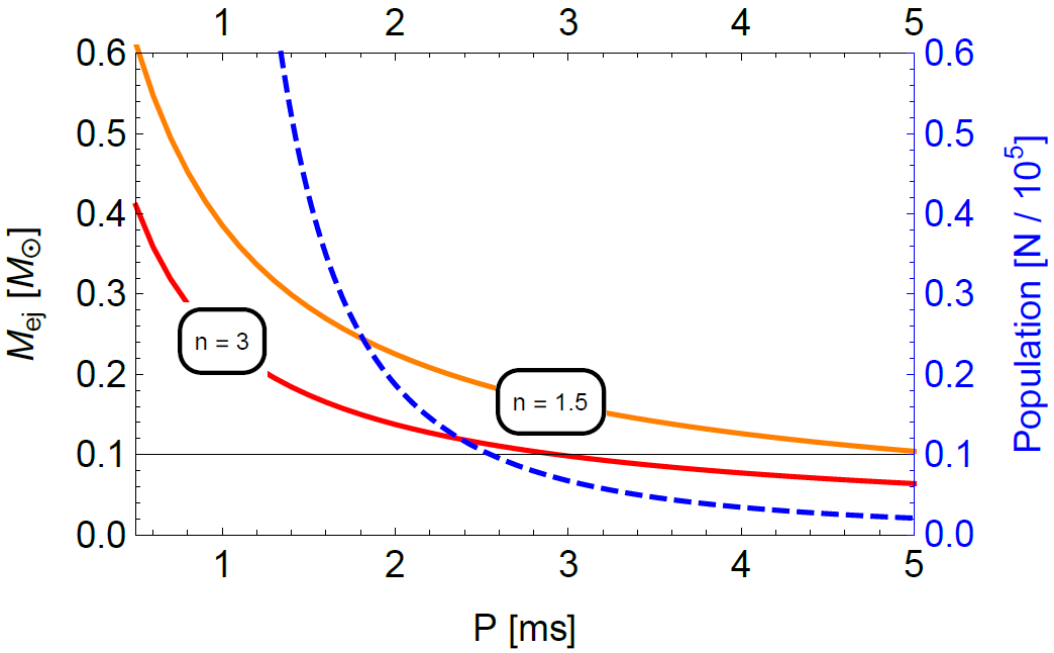

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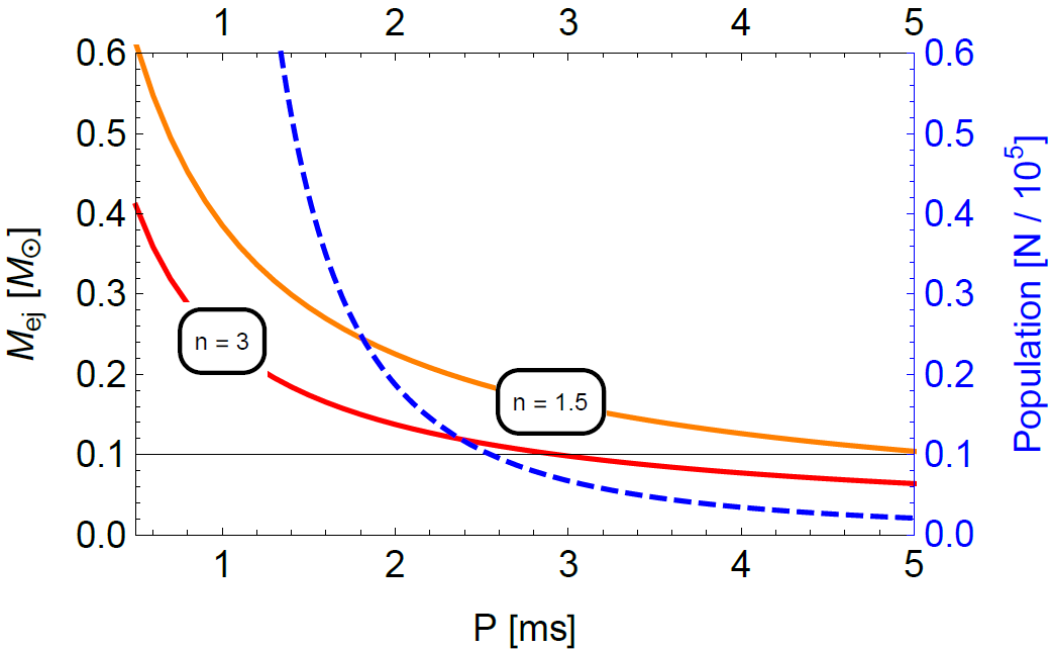

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- Ejecta neutron rich → site of r-process nuclesynthesis?

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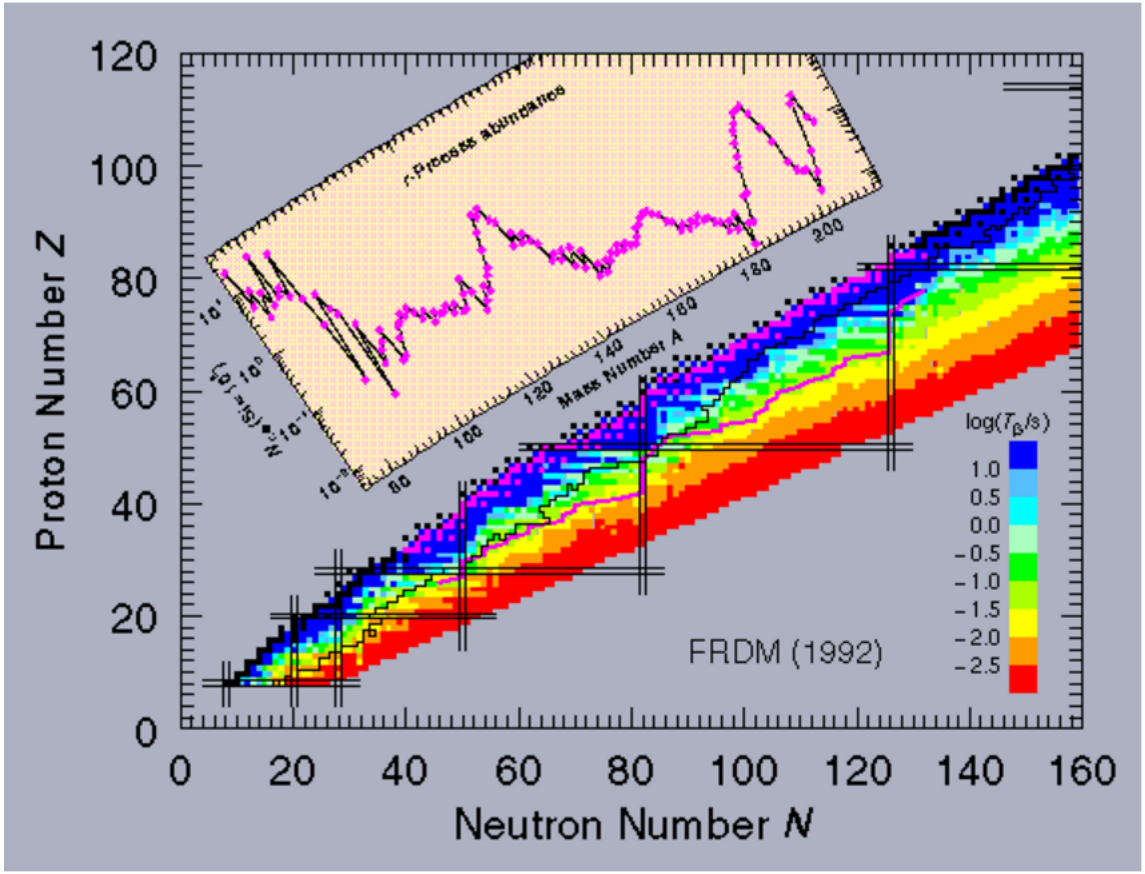

Image: Los Alamos, Nuclear Data Group

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Find amount of r-process material O(10) larger than COM, several orders vs. SN !!

R-process: abundance from PBH-NS

- R-process material in Galaxy: $\sim 10^4 M_\odot$

- Recent UFD observations show consistency with 1 rare r-process event [Ji+,16]

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Amazingly, can explain both simultaneously with PBH-NS !!

* *studied for* WIMP DM [Bramante,Linden,14]

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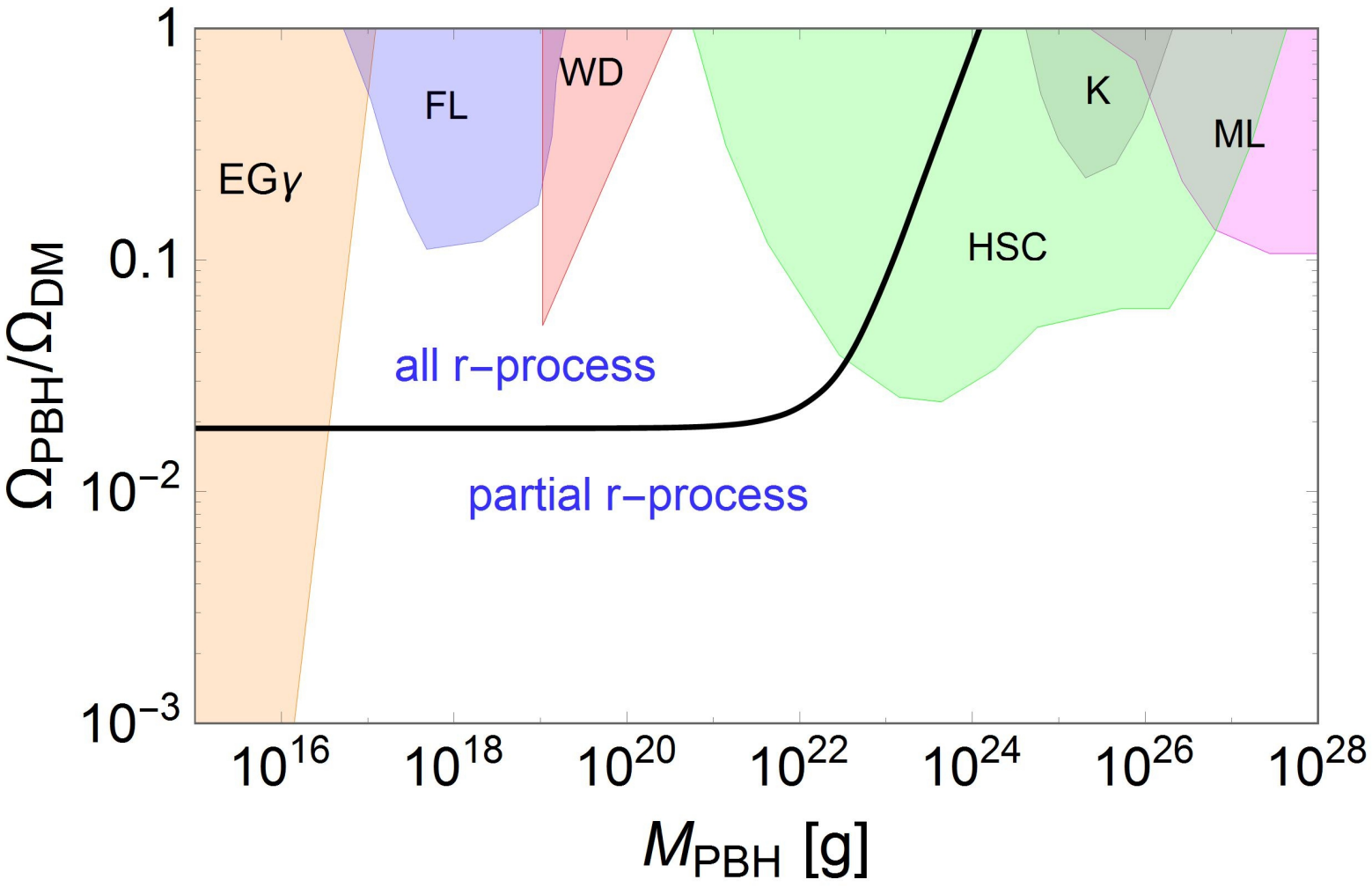

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Fast Radio Bursts (FRB)

- Large energy release stored in magnetic flux tubes, if only (1-10)% of energy converted to radio waves → non-repeating FRB !

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→ tested in upcoming experiments !

Thank You for Attention!